ROUTE RECONSTRUCTION FOR SCANNING OF COMPLEX SURFACES IN THE ROBOTIC SYSTEM

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The robotic system of ultrasonic testing is used for rapid quantitative flaws control of object with complex geometry in various production areas, such as monitoring of fiber composite components in the aerospace and automotive industries, control forms of cast and forged components, control bimetallic diffusion welds and brazed joints. However, ultrasonic testing of complex-shaped objects is required not only using of specialized contemporary equipment, but also implementation of exclusive algorithms that will allow such procedure to be done [1]. One of the most important stages is searching of optimal itinerary for robot manipulator in order to cover the whole investigated surface of objects with minimal effort and time cost as well as completely safe for people. Further, this working stage is considered in more details and described algorithms that were implemented.

The route construction of robot movements starts from loading digital model of real object. Working with computer abstract model allows to conduct all necessary operations using modeling. Moreover, the more accurate model to real sample the more accurate final picture of ultrasonic testing. Object virtual model can be exported from CAD-model or reconstructed from point cloud data obtained using 3D-scanning of the object.

Object surface reconstruction from point cloud data is based on the noise-resistant algorithm suggested in [2]. This algorithm includes Delaunay triangulation and Voronoi diagrams in three dimensions [3] with labeling each tetrahedron is inside or outside the original object, and standard Laplacian smoothing [4] to remove the artifacts created by scanning errors. Such implementation is substantially more robust than several closely related surface reconstruction algorithms [2].

For ultrasonic testing only some selected part of the whole object surface is needed for current analysis. Such surface can be either simple or complex in terms of geometry. The following methods are used to select the right surface on the particular model (each method can be used with an extra indication of certain boundary conditions): for simple (relatively flat) surface and for more complex surface.

In both cases boundary condition (stop searching criteria) will be condition $\beta \leq \omega$, where ω is some threshold value determined by an expert or by experimentation. Also we need to take into account that each variant provides the ability to specify multiple starting points, if the surface of the object is compound or has significant changes in surface geometry ($\beta > 90°$), and it is necessary to make analysis of such surface during one single experiment.

The concept of robot working are based on the principal of moving manipulator from one given point to another on a certain trajectory (straight or curved). Carrying out ultrasonic inspection requires that robot stuck to the sample surface as precisely as possible, and move from one point to another in a straight line. The more complex the geometry of the object, the more control points we need to specify for the exact robot route construction. To obtain the correct ultrasonic picture the manipulator with attached sensor to it must always be strictly perpendicular to the surface of the object to maximize the signal amplitude.

Taking into account the selected area of research, we can analyze it and build a robot itinerary. In this case, the most suitable use of the S-order regular point cloud. This algorithm is based on the concept of plane intersection. The whole testing surface is divided conventionally by cutting planes. These cutting planes define regularity in final point cloud. Each triangle on the surface also defines some plane. Finally, intersection of triangle plane and cutting plane will give us the intersection line, which is used when applying control points.

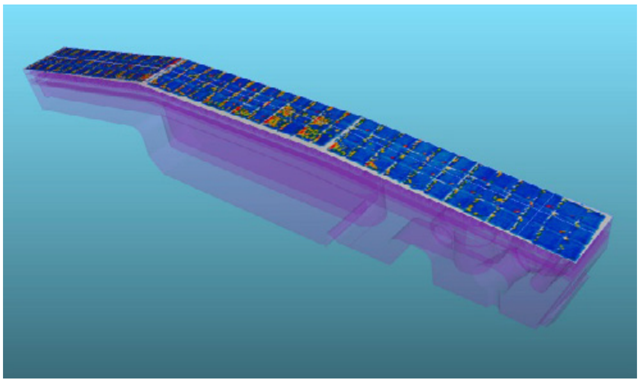

Fig. 1. Ultrasonic picture of flaws in the object

The shorter the distance between the intersecting areas the more accurate the final flaws picture will look (Fig. 1) that is based on the procedure of focusing in each volume element [5]. The distances between the reference points of the route can be any, the main criterion here is that the robot followed perpendicular to the object surface. Therefore, for further optimization if control points are lied on the same line, such points should be removed from output array and left only the start and the end point of that straight. This optimization reduces the amount of data transmitted on the robot itself. Data between the intersecting planes are interpolated by using a bilinear algorithm.

Robotic ultrasonic system offers new possibilities for testing of complex-shaped objects, but also requires the development of new algorithms to proper control such models. The most important component in this process is investigation of the optimal robot itinerary geometry to ensure reproducibility and accuracy of the tests in the specified range.

The implementation of new algorithms allowed to realize the possibility of non-destructive testing of objects with irregular geometry as well as to provide the required test repeatability with ease.

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